NEUTRINO PHYSICS AND ASTRONOMY WITH MACRO

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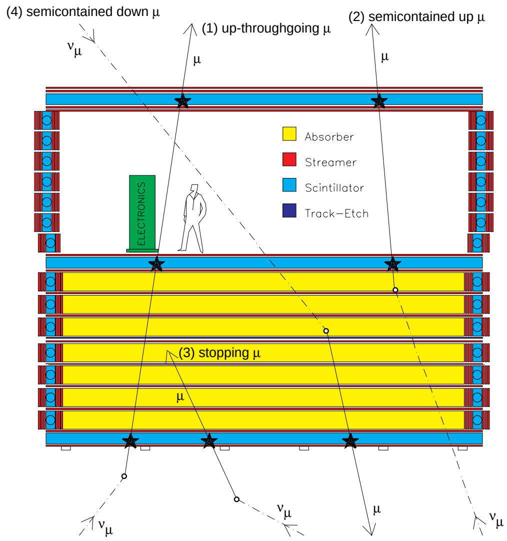
ABSTRACT

MACRO experiment operated in the Gran Sasso underground laboratory. Neutrino events collected by this detector are used in order to study the atmospheric neutrino flux. Different measurements in different energy samples are in full agreement and show evidence of neutrino oscillation phenomenon with maximal mixing and $\Delta m^2 \sim 0.0025\ eV^2$. Also the search for neutrino astrophysical sources is reported.

1 MACRO as an atmospheric neutrino detector

The MACRO detector was located in the Gran Sasso underground laboratory [1]. Thanks to its large area, fine tracking granularity and up-down symmetry, it was a proper tool for the study of upward-travelling muons and neutrino interactions in the apparatus. The different kinds of neutrino events detected by MACRO are shown in Fig. 1A : (1) upward-throughgoing muons, (2) semicontained upgoing muons, (3) upgoing stopping and (4) semicontained downgoing tracks. The sample (1) is due to more energetic neutrinos ($< E_\nu > \sim 50\ GeV$) producing muons also at long distances from the detector. The other samples are due to neutrinos of lower energy ($< E_\nu > \sim 4\ GeV$). The samples (3) and (4) are indistinguishable and therefore they are studied together (3+4).

In Fig.s 1B and 2 the angular measurements are shown for samples (1), (2) and (3+4), respectively. All distributions are so far from the expectation assuming



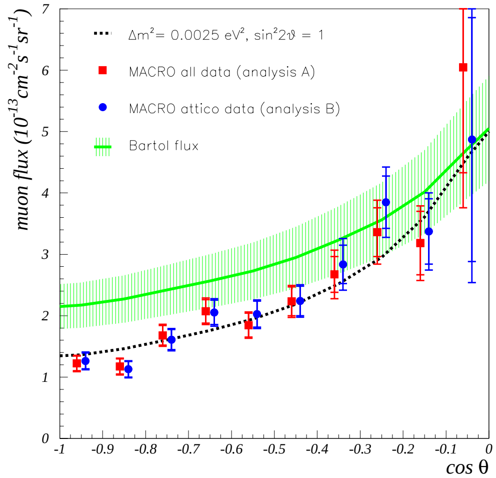


Figure 1: *(A) Atmospheric ν-induced event topologies. (B) Upward-throughgoing muon flux (the results of two different analyses are shown).*

no oscillation. Assuming $\nu_\mu \rightarrow \nu_\tau$ oscillation the measurements become compatible with expectation [2]. The best fit parameters result $\sin^2 2\theta_{mix} = 1$ and $\Delta m^2 = 0.0025\ eV^2$. The measurement of the Multiple Coulomb Scattering [3] permits to estimate the energy of muons in sample (1). Neutrino energies are inferred by means of Monte Carlo methods. In Fig. 3A the data/expectation ratio as a function of estimated L/E_ν is shown. The last point is due to sample (2).

In Fig. 3B the 90% C.L. allowed regions assuming $\nu_\mu \rightarrow \nu_\tau$ oscillation are shown. The smaller area is estimated by normalization and angular distribution of sample (1). The medium area is due to μ-energy estimate for the same sample. The larger area is deduced by (2) and (3+4) low energy samples.

2 Neutrino astronomy

A sample of 1356 upward-travelling muons ($E_\mu > 1\ GeV$) has been studied to look for astrophysical signals [4]. The data do not show ν-excess from selected pointlike sources. Neutrino-induced muon-flux limits have been established at the level of $\sim\ 10^{-14}\ cm^{-2}\ s^{-1}$. Recently the microquasar GX339-4 has been proposed as a source of TeV neutrinos [5]. We note that MACRO detected 7 events in the direction of GX339-4, while 2.3 atmospheric neutrinos were expected [4]. Another analysis searched for high-energy upward-travelling muons due to astrophysical high-energy diffuse neutrinos. No statistically significant signal has been found and an upper limit has been set on diffuse neutrino flux assuming E_ν^{-2} as power law spectrum [6].

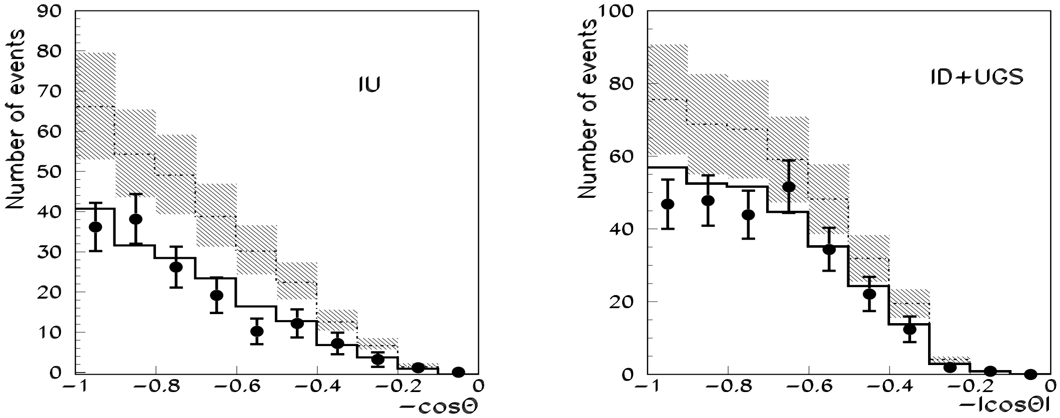


Figure 2: *Angular distributions for samples (2) and (3+4).*

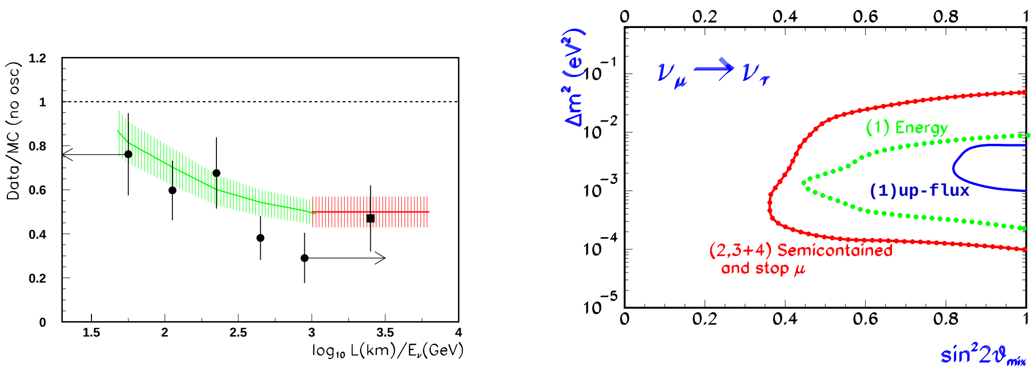


Figure 3: *(A) Data on simulation ratio vs L/E_ν (energy estimate based on Multiple Coulomb Scattering). The curve is obtained assuming $\nu_\mu \rightarrow \nu_\tau$ oscillation. (B) Allowed regions assuming $\nu_\mu \rightarrow \nu_\tau$ oscillation.*

References

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